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Evaluation of Convergent Spray Technology™ Spray Process for Roof Coating Application

by

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Environmental Technology Initiative
Project No. 427
IAG with NASA

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16. ABSTRACT

The overall goal of this project was to demonstrate the feasibility of Convergent Spray Technology™ for the roofing industry. This was accomplished by producing an environmentally compliant coating utilizing recycled materials, a CST™ spray process portable application cart, and a hand-held applicator with a CST™ spray process nozzle. The project culminated with application of this coating to a nine hundred sixty square foot metal for NASA Marshall Space Flight Center (MSFC) in Huntsville, Alabama.

The project was executed in three phases. Phase one involved Independent Research and Development (IRAD) experimentation with materials, formulations, and CST™ spray process. In phase two, the coatings were tested and the spray process was refined. Coatings were applied in two field demonstrations as part of the third phase. Funding for phases two and three was provided by Environmental Technology Initiative (ETI).

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze dev pment and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

The overall goal of this project was to demonstrate the feasibility of Convergent Spray Technology™ for the roofing industry. This was accomplished by producing an environmentally compliant coating utilizing recycled materials, a CST™ spray process portable application cart, and a hand-held applicator with a CST™ spray process nozzle. The project culminated with application of this coating to a nine hundred sixty square foot metal for NASA Marshall Space Flight Center (MSFC) in Huntsville, Alabama.

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

A survey of the roofing industry was performed to determine how CST™ spray process might best serve the market (LJT-31-95MP). Environmentally compliant, low-volatile organic content (VOC) roof paints, coatings, and recycled fillers were investigated. Samples of these materials were evaluated, individually and in various combinations, both for processability and material characteristics. Hand mixes, sprays, and cursory materials testing aided the down-select process.

From these experiments, two final formulations were selected. Two waterborne paints were selected as candidate vehicles for the filler. The filler material selected was ground, treated recycled tire rubber, with or without twenty percent by volume polyester flock (a garment industry byproduct). Later testing indicated the superior elongation of the pure rubber-filled coating verses the rubber/flock-filled, therefore the final product was ten percent by weight pure ground rubber. A portable CST™ spray process cart was designed and constructed, along with a hand-held CST spray wand. These efforts completed phase one.

Refinement of the spray process involved testing the two selected base coatings with a select ratio of filler to establish optimum sprayed characteristics for the paint systems. The neat paints, established industry coatings, served as the baseline to compare with the candidate formulations. Test sprays led to the establishment of spray parameters specific to these materials. Test data is contained in Appendix I.

In August 1996, a demonstration coating was applied to a portion of NASA MSFC Building 4675 roof on Redstone Arsenal. The coating was sprayed over both the galvanized steel aluminum painted substrate and over a foam insulation surface on the same roof. As performance of this coating was monitored, material tests continued.

In April 1997, a coating was applied to the west section roof of NASA MSFC Building 4734 on Redstone Arsenal. Photographs of these roofs and the spray process are located in Appendix II. Real time wear, performance, and weatherability of these coatings will be monitored on a limited basis.

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ASTM D 870	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion
ASTM D 2370	Standard Test Method for Tensile Properties of Organic Coatings
ASTM D 3359	Standard Test Methods for Measuring Adhesion by Tape Test
ASTM G 53	Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

CST	Convergent Spray Technology
EPA	Environmental Protection Agency
ETI	Energy Technology Initiative
F	Fahrenheit
IRAD	Independent Research and Development (IR&D)
MSFC	Marshall Space Flight Center
SRB	Solid Rocket Boosters
UV	Ultraviolet
VOC	Volatile Organic Compound

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EXECUTIVE SUMMARY

A survey of the roofing industry was performed to determine how CST™ spray process might best serve the market (LJT-31-95MP). Environmentally compliant, low-volatile organic content (VOC) roof paints, coatings, and recycled fillers were investigated. Samples of these materials were evaluated, individually and in various combinations, both for processability and material characteristics. Hand mixes, sprays, and cursory materials testing aided the down-select process.

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1.0 INTRODUCTION

1.1 Scope

Task Directive 83, *Commercialization of Solventless Spray Technology for Roof Applications*, is an Energy Technology Initiative (ETI) effort to demonstrate the feasibility of using the Convergent Spray Technology™ spray process in the commercial arena. The goal was to produce an environmentally compliant coating and a portable spray technology for application of materials to environmentally-friendly "green buildings". To remain within the Environmental Protection Agency's (EPA) directive for an environmentally acceptable product, this study focuses on non-bituminous, environmentally compliant materials. While low-VOC coatings are already available in the roofing industry, results from the Task Directive 83 study serve to further reduce VOC emissions and to incorporate the use of recycled materials through the use of CST™ spray process.

1.2 Background

In response to environmental legislation, the roofing industry developed reduced Volatile Organic Compound (VOC) protective coatings for metal and foam roofs. In an effort to further reduce these emission levels, CST™ may be employed to incorporate recycled fillers into the coating system. The addition of fillers serves to decrease the total amount of coating required for a given area, thereby decreasing emissions.

For Task Directive 83, an environmentally compliant coating system was produced using an existing waterborne low-VOC acrylic coating filled with recycled materials - materials which would otherwise be scrapped to a land fill. This coating system was developed to be applied via a CST ™ spray process portable cart system with a hand-held spray applicator.

Materials evaluation and formulations were accomplished under USBI Independent Research and Development (IRAD), as was the construction of the portable cart and spray applicator. Process refinement, test sprays, material testing, and roof spray demonstrations were performed under the task directive.

1.3 CST Background

The CST™ spray process was originally developed to robotically apply highly filled thermal protection coatings to the Space Shuttle Solid Rocket Boosters (SRB) without aid of the solvents normally required for these highly loaded systems. With this technology, high filler concentrations are added to a two-part resin as it exits an air assisted nozzle. Because these pneumatically delivered fillers are added exterior to the nozzle, solvents are not required to reduce the viscosity of the resin/filler mixture. CST technology was also selected by the Air Force to apply thermal protection to the Titan IV payload fairing.

For Task Directive 83, this process was adapted to a portable spray cart with a specially designed spray wand suitable for the commercial roofing industry. This system is especially suited to coat "green buildings". The unique design will accept one- or two-part resin systems and a variety of filler materials.

2.0 MATERIAL SELECTION (Internal IRAD)

2.1 Coating Selection

During the IRAD phase of this project, three commercially available acrylic roof paints were selected to test as base paints for a CST™ spray process candidate coating. Two of these coatings were waterborne vinyl acrylics, one was a waterborne elastomeric. Acrylic was chosen for its durability, economy, ease of use, ultraviolet (UV) resistance, and environmental compliance. Waterborne systems were selected for easy, non-hazardous use and clean-up, as well as their low VOC content. One consideration in selecting the elastomer based material was its ability to withstand contraction and expansion of a metal roof without cracking.

2.2 Filler Selection

A variety of fillers were considered for the acrylic coating system. Materials examined included polyester fabric flock, chopped polypropylene, chopped polyester, rayon flock, nylon flock, chopped recycled tire rubber, polyester monofilament fibers, woolsastonite/silane, mica, and aluminum fibers. The majority of these materials were either recycled or industry by-product materials. Laboratory hand-mixes were made with the fillers and small scale testing of strength, flexibility, and moisture absorption narrowed down the selection. Following are brief comments on some of these fillers.

Polyester flock, a by-product of the garment industry, was easily wetted by two of the paints and proved strong and moisture resistant. The difficulty with this material for CST was in delivering (feeding) the material consistently to the spray applicator, due to its tendency to clump.

Chopped polypropylene did not mix as easily with the tested paint systems. Rayon also appeared to have potential wetting problems. Both materials produced relatively strong coatings, but like the polyester flock, were difficult to feed evenly. Tests showed flock did feed well when mixed with recycled rubber.

Polyester monofilament produced a strong candidate material when hand-mixed. However, monofilaments could not be consistently delivered, through the variety of feeders and end effectors which were tested.

Experimental sprays with mica proved this material too lightweight for satisfactory convergent mixing. Though aluminum fibers produced strong reflective coatings, they were expensive and inflexible.

Recycled tire rubber (with and without polyester flock mixed in) fed through the hopper and end effector easily and mixed well with the waterborne coatings, producing a strong elastic coating. A variety of grades (sizes) of ground rubber were tested, both surface-treated and untreated. Surface treated rubber was found to produce a stronger material than any of the untreated rubber material tested. Various fill levels were examined and tested, ultimately resulting in selection of a system with ten percent by weight ground rubber and ninety percent by weight waterborne acrylic elastomeric paint.

3.0 TEST SPRAYS

From the selection process summarized in Section 2, several series of test sprays were performed with various concentrations of filler ranging from three to forty percent. Results from preliminary sprays helped establish a filler upper level concentration of twenty percent. Both pure rubber and a rubber/polyester flock mixture were sprayed for material tests, in an effort to optimize the final coating system.

Panels were prepared for moisture resistance, tensile strength, elongation, weatherometer aging, and mandrel bend flexibility tests. As part of an IRAD effort, experiments were run with two feed systems and several end effectors. These experiments helped provide an optimum configuration for the portable cart.

4.0 TESTING

4.1 Moisture Resistance

Selected panels were tested for water immersion degradation in accordance with ASTM D 870, *Standard Practice for Testing Water Resistance of Coatings Using Water Immersion*. A stainless steel sample immersion tank with an exterior heating unit was used. The deionized water was circulated with a pump to expose all of the contained water to the atmosphere, which prevented the water from becoming stratified and oxygen depleted. Water bath temperature was maintained at 100 +/- 2°F. Samples were immersed for three quarters of their length in the heated bath, with the water recirculating parallel to the coating substrate. After 24 hours the panels were removed and examined for blistering, color variation, and other indications of immersion damage. Because water effects are sometimes transient, the samples were examined within five minutes after removal. After a 24 hour drying period, in which the samples reached a moisture equilibrium with the atmosphere, specimens were examined for permanent effects, then returned to the water bath for another cycle.

After twenty-seven days, the Vanex systems showed two adhesion failures for both the rubber and rubber/flock filled systems. The Uniflex systems showed some adhesion failures for the rubber/flock systems only, with no failures of the rubber-only filled coatings. All failures were at corners, none were in excess of one quarter square inch. Paint blistering was evaluated with assistance from ASTM D-714, *Standard Test Method for Evaluating Degree of Blistering of Paints*. The results of the immersion test are in Appendix I, Table 1.

4.2 Adhesion

Coating adhesion was tested in accordance with ASTM D 3359, *Standard Test Methods for Measuring Adhesion by Tape Test, Method B*. Adhesion was assessed by applying and removing pressure-sensitive tape over cuts made through the coating to the substrate. Adhesion was rated qualitatively on a 0 to 5 scale. The coatings performance is tabulated in Appendix I, Table 2. Test data indicated the presence of ten percent rubber did not appear to adversely affect the Uniflex adhesion, although slight effects were noted in fifteen and twenty percent filled samples. One Vanex coating, filled five percent with rubber, exhibited slight adhesion failure.

4.3 Tensile Strength and Elongation

This test was performed to determine the strength and elasticity of the filled coatings as free films, when compared with the unfilled (neat) coating. This information reflects the behavior of the coatings subjected to environmental stresses, such as those produced by mechanical wear, aging, and weathering. The results are listed in Appendix I, Table 3. Although strength was considered acceptable for the ten percent 20-flock/80-rubber filled coating, better elongation was obtained from the ten percent pure rubber coating.

4.4 Flexibility Tests (Mandrel Bend)

The coatings were evaluated for flexibility and resistance to cracking on a flexible sheet metal surface, per ASTM D 522, *Standard Test Method of Attached Organic Coatings*. This method is an industry standard used to rate attached coatings for their ability to resist cracking when elongated. Coated panels with various ratios of fillers were cut to four inch by six inch sections, which were bent over cylindrical mandrels of incrementally smaller diameters, ranging from one inch to 1/8 inch. Results are detailed in Appendix 1, Table 4. The Uniflex coatings were found to be very flexible (up to the 30 percent filled level) with both rubber and 20-flock/80-rubber, even when tested on the 1/8 inch mandrel. The Vanex systems failed on the 3/4 and one inch mandrels.

4.5 Water Vapor Permeance

Coatings were evaluated for resistance to the passage of water vapor. Free films of each coating were sealed with wax over an open beaker containing anhydrous calcium chloride desiccant. These beakers were exposed to a controlled atmosphere of 100°F and ninety-five percent humidity for fourteen days. Cups were weighed to determine the rate of water vapor diffusion through the coating. The ten percent rubber filled coating yielded absorption rates most similar to the neat coating. Coatings with filler concentrations in excess of ten percent, both rubber and rubber/flock, yielded slightly higher absorption rates when compared to the neat coating.

4.6 Weatherabili'ʼ

Accelerated atmospheric testing was performed on a series of panels per the summary practice of ASTM G53, *Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials.* This test was conducted in a Weatherometer to simulate the natural effects of cyclic aging, rain, dew, and ultraviolet (UV) radiation exposure. Panels were alternately exposed to cycles of UV light and condensation in a repetitive cycle for a period in excess of 2000 hours. Condensation was produced by exposing the specimen test surface to saturated, heated air and water vapor. Except for a yellowing surface appearance, all of the panels tested exhibited no visual degradation.

5.0 ROOF DEMONSTRATION SPRAYS

5.1 Small Scale Roof Demonstration Spray

On August 16, a field demonstration took place on the standing seam roof of MSFC Building 4675. A waterborne acrylic coating was filled, via Convergent Spray Technology™ equipment, with recycled fillers and applied to the a painted metal roof. A test strip of filled coating was also applied over a small area of foam insulation on the same roof. The roof substrate was prepared two days prior by pressure washing and applying a primer. The filler was a mixture of recycled polyester flock fabric and surface modified recycled tire rubber. The coating has been monitored for wear and weatherability since August 1996. No adverse effects (peeling, blistering, etc.) have been noted to date over either the metal or foam surfaces.

5.2 Large Scale Roof Demonstration Spray

On April 18, 1997, a CST™ spray process coating was applied to the west section metal roof of Building 4734 on Redstone Arsenal in a second field demonstration. Rust spots on this roof were manually removed and spot primed. As before, the roof surface was prepared by pressure washing and application of a primer. A thin overcoat of paint was added to increase light reflectivity; two paneled sections on the southern exposure were left without this thin coating for comparison.

Real time wear, performance, and weatherability of these coatings will be monitored on a limited basis. Photographs of these roofs and the spray operations are located in Appendix II.

6.0 SUMMARY AND CONCLUSIONS

Test sprays and material characterizations aided in the selection of Uniflex waterborne acrylic elastomer paint filled with a ten percent recycled treated rubber-filled coating. Laboratory tests, discussed in Section 4.0, also contributed to this selection. Summaries of the test data are located in Appendix I.

The following laboratory study conclusions resulted in selection of Uniflex paint filled ten percent with recycled tire rubber:

- Uniflex/rubber exhibited more resistance to moisture immersion than Vanex/rubber or Vanex/rubber/flock. Several of the Vanex coatings and two of the Uniflex/rubber/flock coatings began to lose adhesion after prolonged exposure.

- Under all ratios of filled materials tested, Uniflex/rubber and Uniflex/rubber/flock adhered to a flexible substrate as well as the neat paint. Filled Vanex began exhibiting surface cracks over 3/4 and one inch mandrels.

- The tape adhesion test demonstrated strong adhesion of the filled Uniflex coatings at ten percent and below rubber concentration. Uniflex coatings with rubber concentrations of fifteen percent and greater showed slightly degraded adhesion. Vanex coatings with rubber and rubber/flock also demonstrated slight adhesion degradation.

- Tensile strength of the Uniflex system increased somewhat with the addition of the rubber/flock mixture, but coating elongation was lost. When pure rubber was added to the paint, tensile strength and elongation appeared essentially unaffected up to ten percent. Addition of fifteen percent rubber had detrimental effects on the coating elongation.

- Uniflex and Vanex coatings, filled with both rubber and rubber/flock mixtures, exhibited no blistering, peeling, or other visible degradation under 2,000 hours accelerated aging exposure to UV radiation and condensation.

The coating produced for this project was a low-VOC waterborne acrylic elastomeric coating utilizing ground surface-treated recycled tire rubber. Tested properties of the waterborne acrylic paint were not appreciably affected by the addition of ten percent treated rubber. Cost was reduced and recycled materials were utilized. This coating was developed as a

Protective sealant against water-intrusion and corrosion and is intended to extend the service life of a metal roof and minimize maintenance costs. The portable cart developed for this task has multiple application possibilities. It will accept both one- and two-part resin systems, and a wide variety of fillers.

The demonstration sprays on two roofs confirm the feasibility of Convergent Spray Technology™ equipment for application of environmentally compliant coatings to "green buildings". The coatings were applied not only to painted and unpainted metal roofs, but also to a small section of foam insulation. An advantage of the CST™ spray process is the utilization of recycled fillers which would otherwise be scrapped to a landfill. After covering the cost of the recycled treated rubber, an eight percent* overall cost savings was realized with the reduced expenditure for paint.

* See Appendix I for cost savings break down.

Appendix I

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Roof Coating

Table 1: Water Immersion Test

#	Coating	Day 2	Day 4	Day 7	Day 9	Day 13	Day 17	Day 20	Day 22	Day 24	Day 27
1	U10R-1	D	D	D	D	D	D	D	D	D	D
3	VN-1	D	D	D	D	D	D	D	D	D	D
4	V5R-2	D	D	D	D	**6***	D	D	D	D	D
5	U10F-1	D	D	D	D	D	D	D	D	D	D
6	UN-1	D	D	D	D	D	D	D	D	D	D
7	V3F-1	D	D	D	D	D	D	D	D	D	D
8	U3F-1	D	D	D	D	D	D	D	D	D	D
9	U5R-1	D	D	D	D	D	D	D	D	D	D
10	V5R-1	D	D	D	D	D	D	**6***	D	D	D
11	U10F-2	D	D	**3***	D	D	D	D	D	D	D
12	UN-2	D	D	D	D	D	D	D	D	D	D
13	VN-2	D	D	D	D	D	D	D	D	D	D
14	U3F-2	D	D	D	D	D	D	D	D	D	D
15	U5R-2	D	D	D	D	D	D	D	D	D	D
16	U10R-2	D	D	D	D	D	D	D	D	D	D
17	V3F-3	D	D	**5***	D	D	D	**6***	D	D	D
18	U3F-2	D	D	D	D	D	**5***	D	D	D	D
19	VN-3	D	D	D	D	D	D	D	D	D	D
20	U10R-3	D	D	D	D	D	D	D	D	D	D
21	U5R-3	D	D	D	D	D	D	D	D	D	D
22	V3F-1	**2***	D	D	D	D	D	D	D	D	D
23	UN-3	**3***	D	D	D	D	D	D	D	D	D
24	U10F-3	D	D	D	D	D	**5***	D	D	D	D
25	V5R-3	D	**4***	D	D	D	D	D	D	D	D

UN = Uniflex neat
U10R = Uniflex, 10 % rubber filler
U10F = Uniflex, 10 % rubber/flock
V5R = Vanex, 4.5-5 % rubber
U5R = Uniflex, 4.5-5 % rubber filler
U3F = Uniflex, 3 % rubber/flock
VN = Vanex neat
V3F = Vanex, 3 % rubber/flock

Notes:
D Slight discoloration, disappears within 15 minutes
2* Adhesive failure on 2 corners (sample found touching heat element)
3* Pre-test flaw (primer dot)
4* One corner softened, appears to have mechanical damage
5* One corner exhibited slight adhesive failure
6* Adhesion failure corner(s)

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Table 2: Substrate Adhesion by Tape Test

Uniflex Neat	5
Uniflex Neat	5
Uniflex 10% Rubber	5
Uniflex 10% Rubber	5
Uniflex 15% Rubber 1	4.5
Uniflex 15% Rubber 2	5
Uniflex 5% Rubber/Flock (80/20) 1	5
Uniflex 5% Rubber/Flock (80/20) 2	5
Uniflex 15% Rubber/Flock (80/20) 1	5
Uniflex 15% Rubber/Flock (80/20) 2	5
Uniflex 20% Rubber/Flock (80/20) 1	4
Uniflex 20% Rubber/Flock (80/20) 2	5
Uniflex 20% Rubber/Flock (80/20) 3	4
Vanex Neat 1	5
Vanex Neat 2	5
Vanex 5% Rubber 1	5
Vanex 5% Rubber 2	5
Vanex 15% Rubber 1	4.5
Vanex 15% Rubber 2	5
Vanex 5% Rubber/Flock (80/20)	4.5
Vanex 5% Rubber/Flock (80/20)	5
Vanex 15% Rubber/Flock (80/20) 1	5
Vanex 15% Rubber/Flock (80/20) 2	5

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Table 3: Tensile Strength and Elongation

Candidate Coating	Thickness	Max. Stress @ Peak, psi	Percent Strain @ Break, psi
Neat			
Uniflex N	0.039	151	57
Rubber Filled			
Uniflex 5 R	0.039	150	68
Uniflex 10 R	0.032	147	55
Uniflex 15 R	0.037	146	42
80 Rubber/ 20 Flock Filled			
Uniflex 5 RF	0.041	151	58
Uniflex 10 RF	0.036	159	38
Uniflex 15 RF	0.040	161	44

F flock
N neat
R rubber

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Table 4: Mandrel Flexibility of Attached Coatings

Specimen	Mandrel Diameter (inches)	Failure Mode / Test Comments
U neat A	1/2	Passed - No cracks formed
U neat B	3/8	Passed - No cracks formed
U neat C	1/4	Passed - No cracks formed
U neat D	1/8	Passed - No cracks formed
U 5% rubber/flock A	1/2	Passed - No cracks formed
U 5% rubber/flock B	3/8	Passed - No cracks formed
U 5% rubber/flock C	1/4	Passed - No cracks formed
U 5% rubber/flock D	1/8	Passed - No cracks formed
U 15% rubber/flock A	1/2	Passed - No cracks formed
U 15% rubber/flock B	3/8	Passed - No cracks formed
U 15% rubber/flock C	1/4	Passed - No cracks formed
U 15% rubber/flock D	1/8	Passed - No cracks formed
U 20% rubber/flock A	1/2	Passed - No cracks formed
U 20% rubber/flock B	3/8	Passed - No cracks formed
U 20% rubber/flock C	1/4	Passed - No cracks formed
U 20% rubber/flock D	1/8	Passed - No cracks formed
U 20% rubber/flock E	1/2	Passed - No cracks formed
U 20% rubber/flock F	3/8	Passed - No cracks formed
U 20% rubber/flock G	1/4	Passed - No cracks formed
U 20% rubber/flock H	1/8	Passed - No cracks formed
U 30% rubber/flock A	1	Passed - No cracks formed
U 30% rubber/flock B	5/8	Passed - No cracks formed
U 30% rubber/flock C	1/2	Passed - No cracks formed
U 30% rubber/flock D	3/8	Passed - No cracks formed
U 30% rubber/flock E	1	Passed - No cracks formed
U 30% rubber/flock F	1/2	Passed - No cracks formed
U 30% rubber/flock G	3/8	Passed - No cracks formed
U 30% rubber/flock H	1/4	Passed - No cracks formed

Table 4 continued: Mandrel Flexibility of Attached Coatings

Specimen	Mandrel Diameter (inches)	Failure Mode / Test Comments
U 5% rubber A	1/2	Passed - No cracks formed
U 5% rubber B	3/8	Passed - No cracks formed
U 5% rubber C	1/4	Passed - No cracks formed
U 5% rubber D	1/8	Passed - No cracks formed
U 10% rubber A	1/2	Passed - No cracks formed
U 10% rubber B	3/8	Passed - No cracks formed
U 10% rubber C	1/4	Passed - No cracks formed
U 10% rubber D	1/8	Passed - No cracks formed
U 15% rubber A	1/2	Passed - No cracks formed
U 15% rubber B	3/8	Passed - No cracks formed
U 15% rubber C	1/4	Passed - No cracks formed
U 15% rubber D	1/8	Passed - No cracks formed
U 20% rubber A	3/4	Passed - No cracks formed
U 20% rubber B	5/8	Passed - No cracks formed
U 20% rubber C	3/8	Passed - No cracks formed
U 20% rubber D	1/4	Passed - No cracks formed
U 20% rubber E	3/4	Passed - No cracks formed
U 20% rubber F	5/8	Passed - No cracks formed
U 20% rubber G	3/8	Passed - No cracks formed
U 20% rubber H	1/4	Passed - No cracks formed
U 30% rubber A	3/4	Passed - No cracks formed
U 30% rubber B	5/8	Passed - No cracks formed
U 30% rubber C	3/8	Passed - No cracks formed
U 30% rubber D	1/4	Passed - No cracks formed
U 30% rubber A	1	Passed - No cracks formed
U 30% rubber B	5/8	Passed - No cracks formed
U 30% rubber C	1/2	Passed - No cracks formed
U 30% rubber D	3/8	Passed - No cracks formed

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Table 4 continued: Mandrel Flexibility of Attached Coatings

Specimen	Mandrel Diameter (inches)	Failure Mode / Test Comments
V neat A	1	Passed - No cracks formed
V neat B	3/4	Stress cracks - failed at 3/4"
V neat C	5/8	Stress cracks - failed at 3/4"
V neat D	3/8	Stress cracks - failed at 3/4"
V 5% rubber/flock A	1	Stress cracks - failed at 1"
V 5% rubber/flock B	3/4	Stress cracks - failed at 3/4"
V 5% rubber/flock C	5/8	Stress cracks - failed at 1"
V 5% rubber/flock D	3/8	Stress cracks - failed at 1"
V 7% rubber/flock A	1	Stress cracks - failed at 1"
V 7% rubber/flock B	3/4	Stress cracks - failed at 1"
V 7% rubber/flock C	5/8	Stress cracks - failed at 1"
V 7% rubber/flock D	3/8	Stress cracks - failed at 1"
V 15% rubber/flock A	1	Stress cracks - failed at 1"
V 15% rubber/flock B	3/4	Stress cracks - failed at 1"
V 15% rubber/flock C	5/8	Stress cracks - failed at 1"
V 15% rubber/flock D	3/8	Stress cracks - failed at 1"

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Cost Savings Calculation for Uniflex Paint System

Assumptions: Uniflex paint cost $18/gallon in 55 gallon drums

RW4060 rubber cost $0.25/lb. in 50 lb. bags

100 ml Uniflex weighs 151.7 grams

1 gallon Uniflex = 5741.8 grams Uniflex

10% by weight of Uniflex saved per gallon = 574.2 grams = $1.80

574.2 grams rubber costs $0.32

[$1.80 Uniflex saved/gal.]
- [$0.32 rubber spent/gal.]

= $1.48 saved per gallon of coating applied by CST™

$1.48 saved on an $18.00 gallon of paint = 8%

Appendix II

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Roof Coating

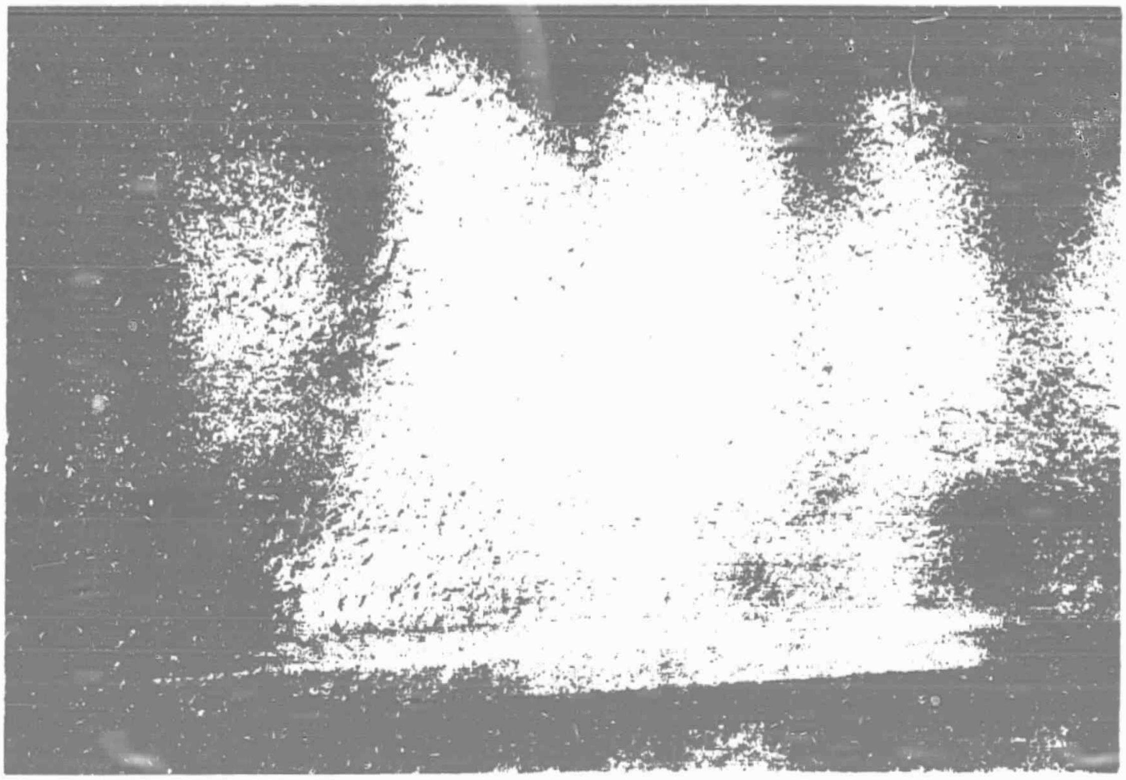

Photo 1. Building 4675—CST™ Roof Coating Over Foam

Photo 2. Building 4675—CST™ Roof Coating Over Metal and Foam

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Roof Coating

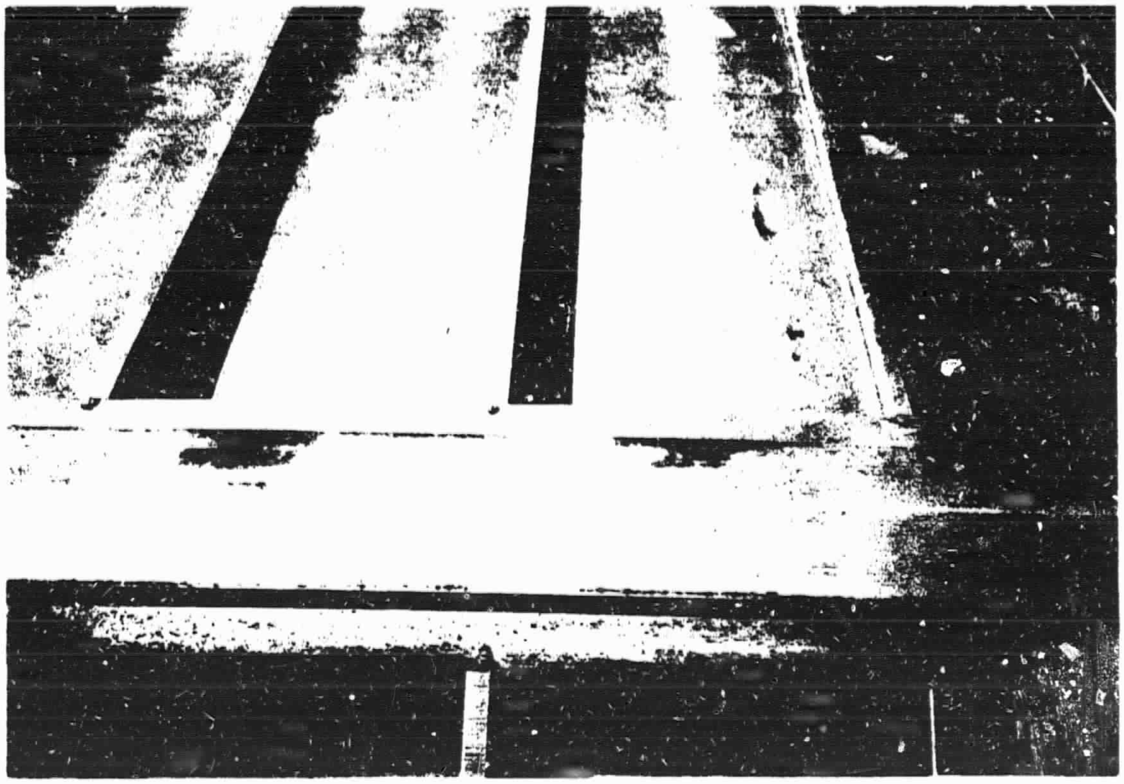

Photo 3. Building 4734—Before Cleaning and Preparation of Roof

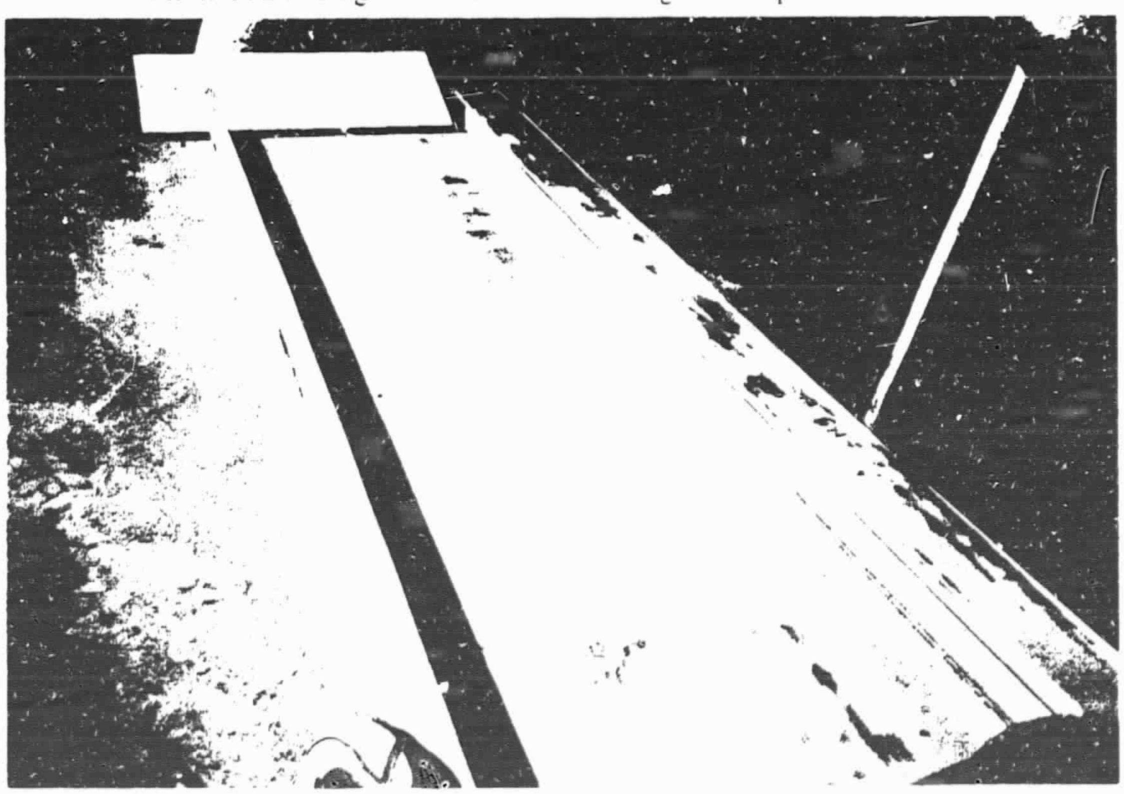

Photo 4. Building 4734—Before Cleaning and Preparation of Roof

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Photo 5. Building 4734—Pressure Washing Operation

Photo 6. Building 4734—Mastic Application for Penetrations

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Photo 7. Building 4734—Priming Operation

Photo 8. Building 4734—Priming Complete

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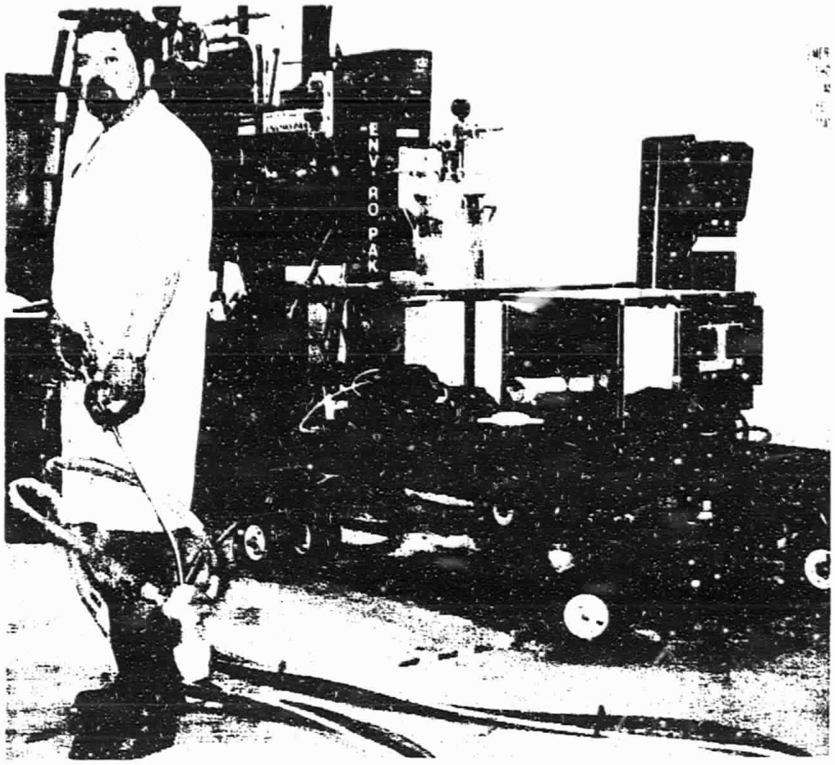

Photo 9, CST™ Cart System

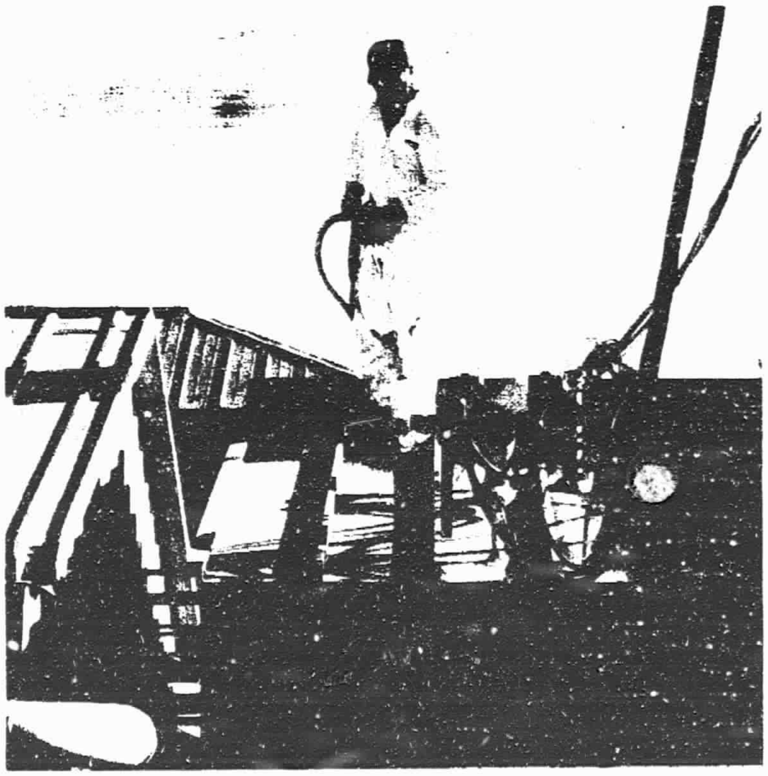

Photo 10, Building 4734—CST™ Spray Operation

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Photo 11. Building 4734—CST™ Spray Operation

Photo 12. Building 4734—CST™ Test Patch without Topcoat South Side with 2 Panels Left Uncoated

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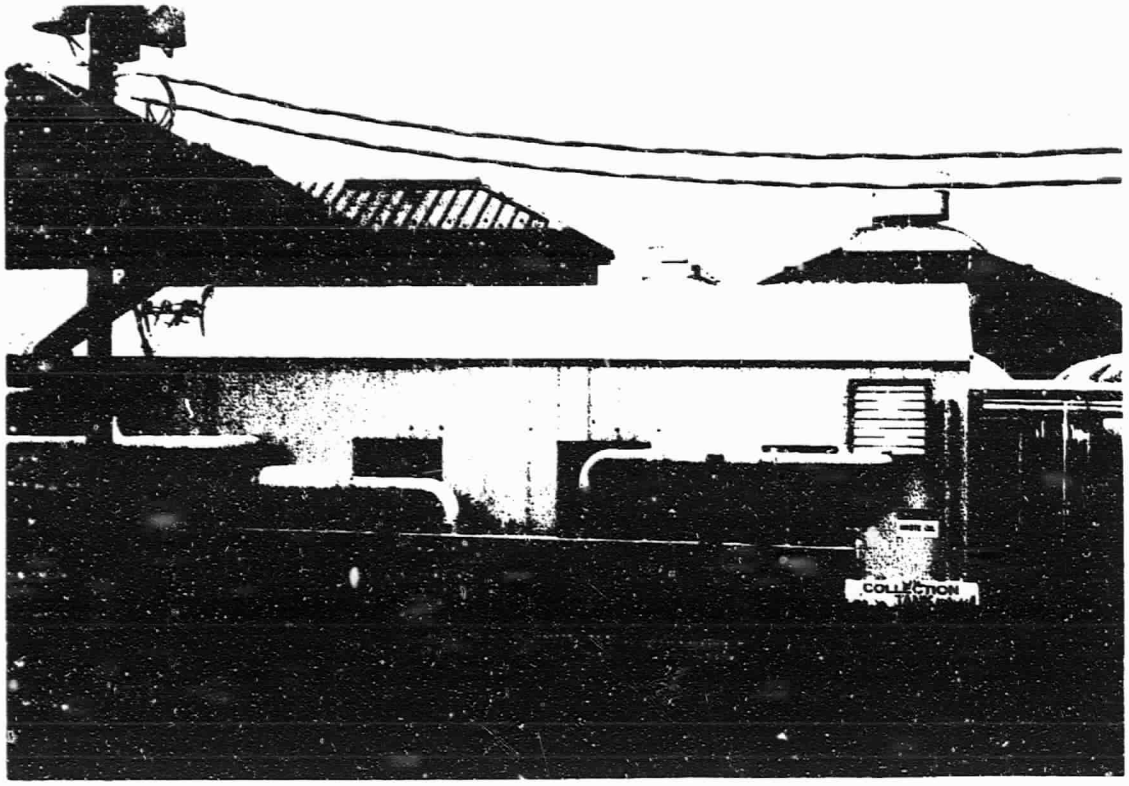

Photo 13. Building 4734—North Side with White Topcoat Applied